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Object processing for action across childhood

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Human adults process and select the opportunities for action in their environment rapidly, efficiently, and effortlessly. While several studies have revealed substantial improvements in object recognition skills, motor abilities, and control over the motor system during late childhood, surprisingly little is known about how object processing for action develops during this period. This study addresses this issue by investigating how the ability to ignore actions potentiated by a familiar utensil develops between ages 6 and 10 years. It is the first study to demonstrate that (1) the mechanisms that transform a graspable visual stimulus into an object-appropriate motor response are in place by the sixth year of life and (2) graspable features of an object can facilitate and interfere with manual responses in an adult-like manner by this age. The results suggest that there may be distinct developmental trajectories for the ability to ignore motor responses triggered by visual affordances and the stimulus response compatibility effects typically assessed with Simon tasks.

Efficient, goal-directed interaction with tools and other utensils during everyday tasks requires rapid recognition of graspable object parts and selection of the appropriate action given the task context. While several studies have revealed substantial improvements in object recognition during perceptual tasks until late into childhood (for review, see Nishimura, Scherf, & Behrmann, 2009), very little is known about how graspable object recognition for action develops. Here, we address this gap in the literature by exploring how the ability to automatically detect and ignore the graspable features of a familiar utensil develops between ages 6 and 10 years.

James Gibson (1977) first introduced the idea that actions originate in the interaction between the visual attributes of an object signalling potential for action (affordances) and the goal of the observer. One item can have countless affordances. For example, a curb might afford a crouching action for sitting or a stepping action for descending onto the street. Utensils such as hammers, pliers, or cups, however, are special objects because they are always associated with a specific function and action. In adults, knowledge of the typical function-related action associated with a utensil can improve the frequency and

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proficiency of these highly practised actions but interfere with less practised ones. For example, Creem and Proffitt (2001) showed that when asked to grasp a spoon to place it on a piece of paper, adults tended to grasp the spoon by its handle, even if grasping it at the bowl would result in a more comfortable movement. The proportion of uncomfortable handle grasps increased when subjects performed a semantic distractor task, indicating greater difficulty in suppressing the overlearned action. Similarly, in a classic study, Tucker and Ellis (1998) showed that when adults discriminated between upright and inverted object pictures with a button press, responses were faster during grasp-congruent trials (handle pointing to the side of the visual field the responding hand is in) and slower during grasp-incongruent trials (handle pointing to the side of the visual field the non-responding hand is in). This effect of object orientation, from here onwards referred to as the *affordance effect*, has been replicated numerous times (Fischer & Dahl, 2006; Pellicano, Iani, Borghi, Rubichi, & Nicoletti, 2010; Phillips & Ward, 2002; Riggio, Iani, Gherri, Benatti, Rubichi, & Nicoletti, 2008; Symes, Ellis, & Tucker, 2005, 2007; Vainio, Ellis, & Tucker, 2007) and even persists if the task does not involve the prime object itself, but only detecting a target on top of the object image (Fischer & Dahl, 2006; Phillips & Ward, 2002). The affordance effect is often attributed to the *Simon effect* (Cho & Proctor, 2010) in which correspondences between task-irrelevant spatial features (a red stimulus presented in left visual hemifield) and spatial elements of task responses (e.g., a left-handed response to a red stimulus) affect reaction time (RT) and accuracy (Hommel, 2011; Simon & Rudell, 1967). Various lines of research, however, suggest that affordance effects cannot simply be reduced to the spatial compatibility effects in Simon tasks. First, affordance effects still occur when spatial asymmetry of the object is controlled for (Fischer & Dahl, 2006; Symes *et al.*, 2007) and they disappear when object graspability is disrupted but asymmetry is maintained (Buccino, Sato, Cattaneo, Rodà, & Riggio, 2009). Second, Simon effects and affordance effects can be demonstrated separately within one task if the location and orientation of a utensil are varied at once (Pellicano *et al.*, 2010; Riggio *et al.*, 2008; Symes *et al.*, 2005). However, while affordance effects disappear with reduced object-based attention, the Simon effect remains, suggesting that different representational levels are involved in the two effects (Symes *et al.*, 2005). In line with this notion, is the fact that the effects have very different time courses: While the affordance effect increases with viewing times up to 1,200 ms (Phillips & Ward, 2002), the Simon effect decays after roughly 200 ms (Hommel, 1994a,b; Kornblum, Stevens, Whipple, & Requin, 1999). Together, these findings suggest that the affordance effect relies on object-based processes rather than on the space-based processes giving rise to the Simon effect. The size of the Simon effect and similar cognitive control tasks typically decreases with age between the sixth and 10th year of life (Casey, Giedd, & Thomas, 2000; Davidson, Amso, Anderson, & Diamond, 2006; Van den Wildenberg & Crone, 2005). However, it is unclear how the affordance effect develops during this period. Addressing this question cannot only provide novel insight into how children deal with familiar affordances in their everyday environment, but also into potential differences and similarities in the developmental trajectories of the Simon and affordance effect.

Sensitivity to the affordances of objects develops early in life. For example, by 4 months of age, the graspability of a target object can determine whether infants will remember the identity or the location of this object (Mareschal & Johnson, 2003). Moreover, by 5 months, infants can pre-shape their hand appropriately for grasping an object solely based on visual information, even though they may not yet possess the motor abilities to use this grasp for picking up the object (Barrett, Traupman, and Needham (2008). By 6.5 months old, infants reach for an object with one or two hands depending on its size, even if the light is turned off after the objects are viewed (Clifton, Rochat, Litovsky, & Perris, 1991). Thus, even by this age, object experience can guide object-directed actions. Furthermore, Barrett, Davis, & Needham, 2007; showed that infants aged 12–18 months are more likely to imitate a novel action successfully when this requires grasping the head of a novel spoon-like tool than when it requires grasping the head of an actual spoon. One possible explanation for the better performance with the novel tool is that infants had difficulty ignoring their knowledge of how spoons are typically grasped (by the handle) when required to grasp them in a more unfamiliar manner. Indeed, after receiving training to grasp the novel tool by the handle (or head) to push balls through a tube, infants showed a similar reduced tendency to grasp the novel tool by the head (or handle) to perform a different task. One fMRI study has explored how sensitivity to familiar affordances develops after infancy. Children aged 6 years and older showed adult-like engagement of hand and grasp-related motor regions in the brain during passive tool viewing in an fMRI scanner (Dekker, Mareschal, Sereno, & Johnson, 2010), suggesting, albeit indirectly, that by the primary school years, visually presented familiar tools activate grasp-relevant motor components without the need for an overt plan to act on these tools. It is unclear, however, to which extent children are able to ignore such well-learned affordances if they conflict with the task at hand.

Various developmental studies have explored planning for end-state comfort, the ability to grasp an object that needs to be rotated to achieve a task goal in such a way that a comfortable end-state position is achieved. This typically involves ignoring the preferred, most comfortable way of acting on the object. The required abilities thus resemble those involved in the affordance effect, in which subjects also need to ignore the preferred (most familiar) affordance to achieve optimal task performance. McCarty, Clifton, and Collard (1999) reported that only by 19 months, infants become able for the first time to ignore their dominant hand and use the hand closest to a spoon handle to avoid an awkward movement when placing the spoon in their mouth. Jovanovic and Schwarzer (2011), however, found that the ability to ignore a preferred thumb-up grasp and select a thumb-down grasp to achieve end-state comfort when placing a bar in a slot was only present in 3-year-olds. The different developmental time courses in these two studies might be explained by the more novel nature of the bar-turning task and particularly the familiarity of the object involved. Indeed, Claxton, McCarty, and Keen (2009; also see McCarty, Clifton, & Collard, 2001) reported that grasps towards spoons or spoon-like tools at 19 months are less effective when the planned action is externally directed than self-directed and hence less familiar. Even for familiar utensils, however, optimization for end-state comfort continues to improve until well into childhood; when 4- to 10-year-olds were asked to grasp and turn a pencil on two heightened bars to draw on a piece of paper, only 10-year-olds showed adult-like grasping strategies. Eight-year-old children also showed adult-like grasp efficiency, but only when the drawing task involved high precision (Thibaut & Toussaint, 2010). Together, these developmental findings suggest that pathways through which visual information about object graspability is transformed into a relevant motor action are present from early in life, but that the ability to manage these motor components during action selection, at least when planning for end-state comfort, continues to develop until well into childhood. While action familiarity can aid efficient grasp planning for end-state comfort in the developing system (Claxton *et al.*, 2009), it might hamper the ability to flexibly choose actions that conflict with the most familiar affordance of the object (Barrett *et al.*, 2007).

To test how familiar affordances are processed across childhood, we employed a child-friendly version of Tucker and Ellis' (1998) paradigm, which allowed us to measure changes in sensitivity to visuomotor affordances between ages 6 and 10 years. Because children preferentially engage grasp-related cortical regions when viewing tools by age 6, we expected that affordance effects are already present by this time. In addition, we hypothesized that the ability to ignore visuomotor affordances that conflict with a current task improves during this period, reflected in an age-related decrease in the size of the affordance effect. We formed this second hypothesis because (1) the effect of stimulus–response compatibility on more abstract stimulus–response tasks such as Simon tasks decreases with age until into after the 10th year of life and (2) because the ability to ignore a comfortable grasp and choose a more efficient but less comfortable one during action end-state planning tasks only becomes adult-like by age 8–10 years.

Methods

Participants

Fifty-eight participants took part in this study. Subjects were divided into three groups, with 20 children aged 6–7 years (7 males, mean age: 7.0 years, $SD = 10.7$ months, 13 females, mean age: 7.2 years, $SD = 7.7$ months), 23 children aged 8–10 (12 males, mean age: 9.4 years, $SD = 9.1$ months, 11 females, mean age: 9.5, $SD = 10.4$ months), and 15 adults (8 males, mean age: 28.9 years, $SD = 4.1$ years, 7 females, mean age: 27, $SD = 2.5$ years). All participants were right handed, had normal or corrected-to-normal vision, and were not colour blind. They were unaware of the true purpose of the study but consented to take part in advance. Parents also gave their informed consent. Data of one child in the youngest age group were excluded due to technical problems.

Stimulus and apparatus

The choice of stimuli and task were motivated by the needs to (1) use a task that is easy to understand for children aged 6 years and upwards and (2) ensure high familiarity with the object across all ages. The stimulus set consisted of two neutrally coloured photographs of a cup with the handle extending to the left or right (Figure 1). The cup had a 12.4° visual angle and was centred on the screen with the sides extending equally far away. The stimulus presentation and recording of responses were controlled using E-prime software (Psychology Software Tools, Inc., Sharpsburg, PA, USA). The images were displayed on a 21 × 34 cm MacBook Pro with a refresh rate of 60 Hz. Importantly, we chose a cup as the stimulus because Buccino *et al.* (2009) used transcranial magnetic stimulation to show that similar cup pictures evoke an enhanced motor response in muscle of the hand on the side of the cup handle, but not when the graspability of the cup was disrupted while visual symmetry maintained, by replacing the handle with a hash symbol. This demonstrates that the affordance effect in response to these types of stimuli is not simply driven by visual asymmetry.

Procedure

The procedure is depicted schematically in Figure 1. Participants were positioned 45 cm away from the computer screen. They kept one index finger on a key with a red sticker and the other on a key with a green sticker, approximately 16 cm apart on the left and right side of the keyboard. Each trial consisted of a 1,500 ms fixation screen, followed by a cup prime with the handle on the left or right side. After a stimulus onset asynchrony (SOA) of 400, 800, or 1,200 ms, a target cross was presented centrally on top of the object. Participants indicated which colour this target was (red or green) by pressing the key with the

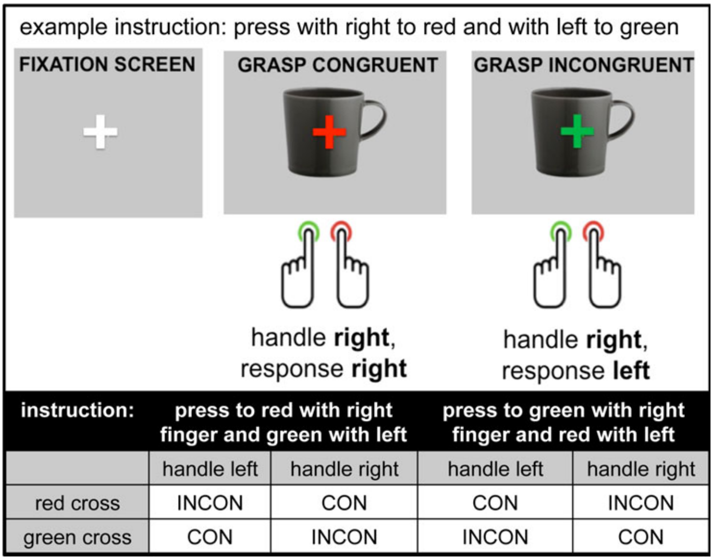

Figure 1. Schematic overview of the experimental design and conditions. The fixation screen was presented for 1,500 ms, and the cup was presented for 400, 800, or 1,200 ms before the target cross appeared and a colour discrimination response was required. A buzz sounded if the response was incorrect. CON, congruent; INCON, incongruent.

corresponding colour as fast as possible. Phillips and Ward (2002) reported that the affordance effect arises gradually with object-exposure time in adults, but the time course along which this happens might be different for children. Including a range of SOAs allowed us to account for and explore any possible influences of such processing speed differences on the affordance effect. During correct grasp-congruent trials, the handle of the cup in the background pointed towards the responding hand and during correct grasp-incongruent trials the handle pointed towards the non-responding hand. A new trial was initiated immediately after the participant responded to the target or after 2 s when no response was given. If the response was incorrect, a brief buzzer alerted the participant.

There were 128 congruent and 128 incongruent trials that collapsed across (1) colour of the cross, (2) side of the cup handle, and (3) finger/response mapping as described in Figure 1. There were two blocks, each containing 40 trials with an SOA of 1,200 ms, 44 with an SOA of 800, and 44 with an SOA of 400 ms. SOA, the colour of the cross, and the side of the handle were varied within block, in random order. The response mapping between the hand and colour of the cross (press left to green, press left to red) was switched in between blocks with the order counterbalanced within each group. During five fixed breaks, participants were encouraged to keep responding as fast as possible.

Results

We explored the effects of age, handle/response grasp congruency, and SOA on RT and task performance. The results are reported separately for each condition in Table 1. The responses were filtered before analysis. Filter methods were replicated from Phillips and Ward (2002), who employed a similar design to ours. Erroneous trials were excluded from the RT analysis. Of 256 trials, the mean number of wrong responses in each age group was 6.75 (SD = 4.4) in adults, 13.4 (SD = 8.4) in 8- to 10-year-olds, and 11.8 (SD = 9) in 6- to

Table 1. Mean reaction times and number of included trials are displayed separately per grasp-congruency condition, SOA, and age group

	Reaction time (ms)			No. of correct response trials		
SOA	400	800	1,200	400	800	1,200
Adults						
CON	417 (36.6)	400 (38.3)	395 (42)	43 (1.1)	43 (1)	39 (1.2)
INCON	440 (42.7)	423 (44.5)	424 (48.8)	42 (1.7)	41 (1.8)	38 (1.6)
Difference	23	23	24	1	2	1
8–10 years						
CON	643 (109)	604 (113.7)	619 (110.1)	40 (3.9)	41 (3)	37 (3.7)
INCON	662 (114.5)	645 (119)	639 (112.7)	38 (4.2)	39 (3.4)	36 (2.9)
Difference	19	41	20	2	2	1
6–7 years						
CON	781 (93.4)	753 (102)	750 (89.1)	37 (5.5)	39 (3.7)	36 (3.6)
INCON	800 (92.7)	787 (97.1)	799 (100.3)	37 (5.1)	37 (5)	34 (3.9)
Difference	19	34	49	0	2	2

Notes. Standard deviations are reported in brackets.
SOA = stimulus onset asynchrony; CON = congruent; INCON = incongruent.

7-year-olds. In addition, trials with responses more than three standard deviations above or below the grand subject mean (outliers) were removed, as were trials with RTs faster than 200 ms (anticipations) and slower than 1,200 ms (slow responses). In replication of Phillips and Ward (2002), this additional fixed cut-off filter was applied in addition to outlier removal because slow responses (possibly influencing the outlier criterion if there are many) are likely to be affected by confounding factors such as attention lapses and may hence be a less clean measures of affordance effects. We employed a more lenient upper time limit than the 1,000 ms used by Phillips and Ward (2002) to allow for slower response times in younger children, but upon reanalysis with response times below 200 and above 1,000 ms excluded, the pattern of results was identical. Therefore, only the data obtained with the more lenient 200–1,200 ms filter are reported here. The mean number of trials excluded by applying the RT filter was 3.7 for adults (SD = 2), 13.6 (SD = 13.7) for 8- to 10-year-olds, and 22.65 (SD = 20.1) for 6- to 7-year-olds, reflecting that very slow/inattentive responses were more frequent in younger children. Because the low overall number of errors hampered the power of the accuracy analysis, we combined error trials with the trials with invalid response times and termed the compound measure *correct response trials*.

To explore how congruency between affordance and response affected RTs at different ages, a three-way ANOVA was performed with congruency (grasp congruent and grasp incongruent) and SOA (400, 800, and 1,200 ms) as within-subject factors and age (6- to 8-year-olds, 9- to 10-year-olds, and adults) as between-subject factor. Degrees of freedom were adjusted using Greenhouse–Geisser corrections when appropriate. Figure 2, top left, shows RTs to the colour of the cross during grasp-congruent and grasp-incongruent trials for each age group separately. Grasp congruency clearly effects response times at all ages, with faster responses on average during congruent than incongruent trials (adults responded 33 ms faster, 8- to 10-year-olds 27 ms faster, and 6- to 7-year-olds 25 ms faster, main effect congruency: $F(1, 55) = 90.3$, $p < .001$, $\eta_p^2 = .62$. In addition, overall RTs decreased with age, $F(2, 55) = 68.5$, $p < .001$, $\eta_p^2 = .73$. However, in spite of different overall RTs, the size of the affordance effect remained consistent from 6 to 8 years

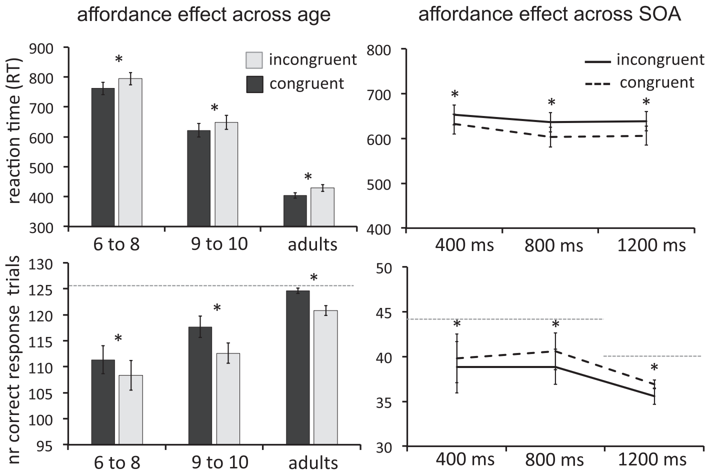

Figure 2. Reaction times (top) and number of correct response trials (bottom) and standard errors are displayed separately for grasp-congruent and grasp-incongruent trials for the three different age groups (left) and stimulus onset asynchronies (SOAs; right). $^*p < .01$. The line in the bottom graphs indicates the total number of trials per condition.

onwards, Age × Congruency: $F(2, 55) = 0.81$, ns. Figure 2 top right, depicts the RTs during congruent and incongruent trials per SOA, collapsed across age. The graph shows that overall response speed depended on SOA, $F(2, 54) = 18.2$, $p < .001$, $\eta_p^2 = .40$. In addition, the congruency effect became more pronounced with longer SOAs (20.5 ms at 400, 33.6 ms at 800 ms, and 32.3 ms at 1,200 ms, Congruency × SOA: $F(2, 54) = 3.3$, $p = .044$, $\eta_p^2 = .11$, in line with previously reported findings with adults (Phillips & Ward, 2002). In addition, there was a marginally significant three-way interaction between age, SOA, and congruency, $F(4, 110) = 2.39$, $p = .056$, $\eta_p^2 = .08$. This interaction was driven by a shift in latency of the congruency effect with 6- to 7-year-olds showing the largest effect at SOA 1,200 ms, 8- to 10-year-olds at SOA 800 ms, and with adults showing a more consistent effect size across the board (Table 1). No other ANOVA results reached statistical significance (all F values < 0.81, p = n.s.). To investigate whether the developmental consistency of the affordance effect was an artefact of the shorter mean RTs at older ages and in fact reflected a *relative increase* in the size of the effect, we performed three control analyses. First, a three-way ANOVA revealed that there were no significant age differences in the relative size of the affordance effect when differences in RT during grasp incongruent and congruent trials were expressed as proportions of subject's mean RTs, $F(2, 57) = 1.23$, $p = .302$. Second, there was no significant correlation between the size of the affordance effect and mean RT after correcting for age (Pearson's $r = .19$, $p = .16$), suggesting that the affordance effect is independent of RT when age differences in mean RT are accounted for. Finally, we attempted to explore whether consistency in the size of the affordance effect still persisted in subsets of differently aged subjects matched on mean RT. The number of child subjects that could be matched to adults on this measure was insufficient for an informative analysis ($n = 5$). We did, however, perform a matching analysis across the two groups of children in which we compared the 10 fastest children aged 6–7 years (708 ms, $SD = 63.4$, mean age: 7.0 years) with the 12 slowest children aged 8–10 years (721 ms, $SD = 76.5$, mean age: 9.3 years). These subjects were selected for matching based on their overlapping range of mean RTs. A repeated-measures ANOVA did not reveal a significant age by congruency interaction, $F(1, 20) = 0$, $p = .99$, suggesting that the developmental consistency of the size of the affordance effect across these age groups cannot be explained by differences in mean RT. Altogether, these analyses suggest that differences in the size of the affordance effect were independent of overall RT. It thus seems unlikely that the constant affordance effect across age in fact reflected an age-related decrease in sensitivity to familiar affordances.

Another three-way ANOVA was performed to compare the effect of congruency between affordance and response on the number of correct response trials across age. The results are consistent with the RT analysis. The number of correct response trials was significantly higher on grasp-congruent trials than on grasp-incongruent trials (a difference of 3.8 trials in adults, five trials in 8- to 10-year-olds, and three trials in 6- to 7-year-olds, main effect of congruency: $F(1, 55) = 25.7, p < .001, \eta_p^2 = .32$, indicating that all participants responded incorrectly or too slowly more frequently when the handle of the tool prime and the responding hand were on different sides. Again, there was no significant interaction between age and congruency, $F(2, 55) = 0.52, p =$ n.s., although there were more correct response trials with increasing age on the whole, $F(2, 55) = 12.5, p < .001, \eta_p^2 = .31$. As can be seen in Figure 2, bottom right, the number of included items also depended on SOA, $F(1.74, 95.57) = 53.5, p < .001, \eta_p^2 = .49$, with the fewest correct response trials at the longest SOA, in line with the slightly reduced overall number of trials in this condition. There was an interaction between SOA and age, $F(3.48, 95.57) = 4.163, p = .006, \eta_p^2 = .13$, revealing that age-related increases in the overall number of correct response (irrespective of whether these occurred during congruent or incongruent trials) were more pronounced at shorter SOAs, probably due to increasing visual processing speed. There were no other significant results of the ANOVA, so the size of the affordance effect was not significantly modulated by SOA in any of the age groups (1 trial difference at 400 ms, 1.7 trials at 800 ms, and 1.3 trials at 1,200 ms, all remaining F values $< 2.01, p =$ n.s.).

Discussion

We investigated children's abilities to automatically detect and ignore familiar affordances in the environment. This is the first study to test directly how merely seeing a tool in the background influences manual actions between ages 6 and 10 years. Based on previous research with infants, toddlers and children that suggested that adult-like sensitivity to affordances of familiar utensils develops early in life but that action selection might develop later, we expected that an affordance effect would be present across this entire age range but would be more pronounced in younger children. The results indeed reveal that already by 6 years of age, manual responses to the colour of a target are faster and more accurate when they are congruent with grasping a cup handle in the background than when they are incongruent with grasping the handle. Thus, while aspects of object recognition for perception such as configural processing (Rentschler, Jüttner, Osman, Müller, & Caelli, 2004) and recognizing objects in cluttered scenes and under unusual viewpoints or lighting circumstances (Bova *et al.*, 2007; Yoon, Winawer, Witthoft, & Markman, 2007) continue to improve substantially until into the teens, implicit recognition of actions associated with familiar objects is adult-like by age 6–8 years. In line with these findings, an adult-like preference for passively viewed tools was detected in motor and grasping regions in the brain by the age of 6 (Dekker *et al.*, 2010).

Unexpectedly, there were no significant age-related changes in the size of the affordance effect, even though younger children responded more slowly and less accurately overall. Thus, the ability to ignore familiar affordances during a colour discrimination task is adult-like by age 6–7 years. The developmental consistency in the affordance effect is particularly surprising when considering the development of two other types of motor response control. First, ignoring salient affordances when planning for end-state comfort continues to develop until at least 8 years (Thibaut & Toussaint, 2010). What might explain the earlier emergence of adult-like performance that we report here? Planning for end-state comfort does not only involve ignoring a preferred affordance but also requires planning skills, unlike the current colour discrimination task. It might be the planning element of end-state comfort planning tasks that may drive its protracted development. Another possible explanation is that response difficulty is matched better across age in the current task; end-state efficient grasps might be less comfortable at younger ages due to lower dexterity, smaller hand size, or immature low-level motor skills. Thus, the balance of 'costs' associated with planning for end-state comfort versus using a more comfortable initial grasp may be different for adults and children. If so, this could reduce frequencies of end-state planning grasps at younger ages, even if children are in principle able to select adult-like grasp strategies when action difficulty is matched across age (Jovanovic & Schwarzer, 2011). The current paradigm circumvents this potential problem because button-press motor responses are very simple and, crucially, were kept identical across conditions. A second reason why the current findings are surprising is because the need to ignore distracting affordances during colour discrimination closely resembles the need to ignore distracting information during cognitive control tasks such as Simon or Stroop tasks. It has been reported numerous times that performance on such response inhibition tasks improves substantially until late in childhood and even adolescence (Casey *et al.*, 2000; Van den Wildenberg & Crone, 2005). This raises the possibility that the affordance effect and the Simon effect are dissociated during development, which would support the idea that the mechanisms underlying these two tasks are different and depend on object- versus space-based representations (Symes *et al.*, 2005). The development of the Simon effect and similar indices of cognitive control during childhood has been associated with maturation of fronto-striatal networks in the brain (Casey, Galvan, & Hare, 2005; Durston, Thomas, Yang, Ulug, Zimmerman, & Casey, 2002). It is possible that the development of the affordance effect relies on a different and presumably earlier maturing parieto-frontal network of brain areas that have been linked to the affordance effect in adults (Grezes, Tucker, Armony, Ellis, & Passingham, 2003). In addition, in line with previous reports (Phillips & Ward, 2002), the effect of object affordance on RT became more pronounced with increasing SOA from 400 to 1,200 ms. This contrasts with the time course of the Simon task in which the effect typically decays after 200 ms (Hommel, 1994a,b; Kornblum *et al.*, 1999). Future studies should explore a potential developmental dissociation of the Simon and affordance effect further by comparing the Simon task and the current paradigm at different ages within the same participants.

In conclusion, this study is the first to demonstrate that the mechanisms that transform a graspable visual stimulus into an object-appropriate motor response are in place by the sixth year of life and that graspable features of an object can facilitate and interfere with manual responses in an adult-like manner by this age. The findings are consistent with the notions that (1) visuomotor affordance processing matures early in childhood and that (2) the mechanisms underlying the affordance effect and the Simon effect are not identical.

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